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METHOD AND SYSTEM FOR CONDENSATION OF UNPROCESSED ~~WELL STREAM~~ FROM OFFSHORE GAS OR GAS CONDENSATE FIELD

Technical Field

The present invention relates to a method of condensing an unprocessed well stream from an offshore gas or gas condensate field for the purpose of producing a condensed well stream product that can be collected in a storage tank at sea for transport therefrom to land.

Background Art

The development of offshore gas or gas condensate fields of smaller size has often been considered as unprofitable because the costs of bringing the product therefrom onto the market would have been to high. Using technologies known thus far often requires complicated preprocessing and production plants for the preparation of products which are more suitable for the transport away from an exploitation field than an unprocessed well stream. In particular it has been common practice to separate liquids and solid particles, and any heavier hydrocarbons, from the well stream and then to process further constituents of the well stream individually, such as the extracted gas.

An example of the prior art is described in NO Patent No. 180 469 which relates to a method and system for offshore production of liquefied natural gas (LNG), wherein the well stream is supplied from a subsea production plant to a pipeline, in which it is cooled by the surrounding sea water. Then the well stream is supplied to a conversion plant provided on a ship, wherein liquids and solid particles are extracted and at least a part of the remaining gas is converted to liquid form for the transfer to storage tanks on board the ship.

Another example of the prior art is described in US Patent No. 6 378 330 which relates to a process for making pressurized liquefied natural gas (PLNG) from a gas stream rich in methane, wherein gas is condensed by first being cooled and then expanded. If the stream of natural gas contains heavier hydrocarbons which may freeze out during the liquefaction, they must, however, be removed prior thereto.

Furthermore, NO Patent No. 177 071 describes a method of dealing with petroleum gas from an oil or gas production field comprising ethane and heavier hydrocarbons, wherein liquids and solids are separated from a well stream and the gas of the well stream is

dried, cooled and possibly processed further prior to condensation and the placement of the condensed gass in storage tanks. In US Patent No. 6 094 937 it is described a method of liquefaction and/or conditioning of a compressed gas/condensate from a petroleum deposit, especially a compressed gas/condensate flow which has been separated from a crude oil extracted from an offshore oil field.

Using the technologies known thus far and disclosed in the above publications, the feed is in each case subjected to a preprocessing prior to the condensation process itself. In particular it is presupposed that liquids and solids, and any heavier hydrocarbons, are separated in advance. The known techniques referred to all focus on making liquefied natural gas of some quality or other, that may be brought ashore from a location at sea. None of the publications is seen to be concerned with the other constituents of the well stream. According to NO Patent No. 180 469, for example, the extracted liquids and solids are transferred to a container with no indication as to what is done with the contents of the container when it is full.

Threrefore, in such offshore production of liquefied natural gas, there may be a problem in respect of such components that traditionally are extracted, such as oily sands and water, which must be transported away, or otherwise be deposited *in situ*. Common to the approaches disclosed in the publications above is that they also require costly processing plants, some times drier/dehydration and regenerator/cleaning systems, too.

Thus, there is a need for a technological solution, by means of which smaller gas or gas condensate fields can be developed in a more cost efficient manner than by the technologies known so far.

Disclosure of Invention

The invention relates to a method of condensing an unprocessed well stream from an offshore gas or gas condensate field, wherein the well stream is fed from one or more wellheads through a pipe coil in the sea to be cooled by the surrounding water to a temperature just above the hydrate temperature of the well stream, and then feeding the cooled well stream to an expander for the expansion thereof.

On this principle background of prior art, the method according to the invention is characterized in that the unprocessed well stream is expanded isentropically, or near isentropically, to a state in which the pressure is close to that of a storage tank, such

that part of the well stream is condensed, and condensed fractions of the prior to the expansion, unprocessed well stream are drawn off the expander and fed to the storage tank along with condensation products from the exit of the expander, thereby producing, without any preprocessing, a condensed well stream product made up of a mixture of liquids and solids which are collected in the storage tank for transport therefrom to land.

The invention also relates to a system for carrying out the method according to the invention, such as indicated in patent claim 8 appended hereto, and preferred embodiments of the invention are indicated in respective ones of the dependent claims.

In the method according to the invention there is no need for the well stream to undergo any form of preprocessing, not even separation. Hence, a processing plant for the implementation of the method may be correspondingly simplified. The method makes it possible to condense an unprocessed well stream into a product comprising a mixture of liquids and solids, *i.e.* a liquefied unprocessed well stream (LUWS), without any preprocessing of the feed, such as extraction of solid particles, *e.g.* sands, and removal of water, cleaning and drying.

In the context of the present invention, as it would be known in the present professional area, the expression "unprocessed well stream" is intended to mean the mixture that flows out of a well through a wellhead, or more wellheads joined in a manifold, under the normal production from a gas or gas condensate field without any preprocessing being undertaken, and of a composition, pressure and temperature that may vary from one field to another. An unprocessed well stream as just defined, may contain all possible components and phase mixtures that normally occur when producing from a gas or gas condensate field. Such a flow of fluids is the feed to the process of the invention.

Brief Description of Drawings

An example of how to carry out the method according to the invention is given below by reference to the accompanying drawings, wherein:

Figure 1 is a block diagram showing an embodiment of the invention, in which the final cooling is done by means of a heat exchanger and a cooling device included in the process chain,

Figure 2 is a block diagram showing an alternative embodiment of the invention, in which the final cooling is done by means of a cooling device in the form of a rechargeable, portable cooling energy accumulator,

Figure 3 is an example of a pressure *vs.* enthalpy diagram showing the changes in the state of a well stream during a process according to the invention, and

Figure 4 is a diagram that based on process pressure illustrates the difference between a process performed according to the invention and a conventional condensation process.

Modes for Carrying Out the Invention

Figure 1 is a block diagram showing an embodiment of the invention, which is adapted to a process whereby an unprocessed well stream from a wellhead or well manifold is condensed by expansion and led to a storage tank, and the final cooling is done by means of a heat exchanger and a cooling device included in the process chain.

This embodiment of the invention illustrated in Figure 1 is intended for being used for the condensation of an unprocessed well stream from an offshore gas or gas condensate field. Through a wellhead 1, or a plurality of wellheads interconnected at a collector manifold, gas is produced, the composition, pressure and temperature of which depending on the field concerned. Without any preprocessing or treatment the well stream 2 is led through a cooling loop 3 such that the temperature of flow is kept a few degrees, *e.g.* 5°C, above the hydrate forming temperature of the well stream. From the cooling loop 3, which may take the form of a coiled pipe on the sea bed, the well stream is fed to a multi-stage expander means 4 which may be a dynamic expander, or the combination of a static and a dynamic expander.

An example of a conceivable dynamic expander suitable for utilization in the expansion process which tolerates the formation of ice and the wear and tear due to ice particles is described in US Patent No. 4 771 612, whereas examples of conceivable static expanders for the same purpose are described in each of US Patents No. 5 083 429 and 6 372 019. It also feasible to use some other expanders which are suitable for the purpose.

In the expander 4 the pressure and temperature is gradually lowered such that parts of the well stream is condensed, and liquids are drawn off through draining outlets 5A. The condensation products from the drains are fed to a mixing vessel 6 which also is supplied with the condensation products from the exit of the expander 5B which on their part is cooled to a desirable temperature prior to the mixing by means of a system comprising a heat exchanger 8 and a cooling device 9 included in the process chain. Thus, the product then accumulating in the storage tank 7 is a condensed well stream

product, *i.e.* a liquefied unprocessed well stream (LUWS) made up of a mixture of condensation products from each of the draining outlets 5A and the expander exit 5B.

Figure 2 is a block diagram showing an alternative embodiment of the invention, in which the process is the same as that in Figure 1 but where the final cooling prior to the arrival of the condensation products at the mixing vessel 6 is done by means of a cooling device which in this case is in the form of a cooling energy accumulator 9 adapted to be recharged ashore and transported to the gas or gas condensate field.

A process according to the method of the invention is now to be explained with reference to Figure 3 which gives an example of a pressure *vs.* enthalpy diagram showing the changes in the state of a well stream during the process. In the pressure *vs.* enthalpy diagram shown the point labelled 6 indicates the state of the well stream at the wellhead 1. The well stream emerging from a gas or gas condensate field is at a high temperature, *e.g.* of 90°C, and a high pressure, which in the diagram shown equals 200 bar. Through the cooling loop 3 the well stream is cooled to a temperature just above the hydrate temperature, corresponding to state 5 in Figure 3. Then the well stream is expanded isentropically, or near isentropically, to a state 3 in which the pressure is close to that of a storage tank 7.

During the expansion process 5 → 3 part of the well stream condenses and the condensed fraction is led to the storage tank 7 through draining outlets arranged on the expander 4 at the same time as energy is released which is convertible to electric power, as indicated by a generator 10 in Figures 1 and 2, approximately corresponding to the shift in enthalpy $h_5 - h_3$. To cause the well stream to become a mixture of liquids and solids the well stream is cooled from state 3 to state 7. For this cooling the energy released from the expansion 5 → 3 is used in addition to an external energy source 11 where required, *e.g.* from a ship. In this example, the pressure in the storage tank is chosen to be 15 bar but it may be set as low as 1 bar, if this is practical. In such an example the expansion would proceed from 5 → 2 and subsequently the mixture would be cooled from 2 → 1 after the expansion process.

The difference between the process according to the invention and the conventional LNG processes is elucidated in Figure 4. According to the invention the condensation

takes place along the solid linje (a) in a fully continuous process from wellhead or wellhead manifold to the storage tank 7. On the contrary, the conventional condensation processes take place in a step by step manner and the well stream must undergo a comprehensive preprocessing including separation, drying, cleaning corresponding to points 2 and 4 i Figure 4, and recompression corresponding to points 3 and 5 in Figure 4, several times, before it arrives at the storage tank.

One advantage of the invention is that the unprocessed well stream is used as feed to the process. This means use of fewer elements of equipment and, hence, weight and space savings on platforms and production ships at sea, resulting in considerable cost reductions compared to common condensation processes. In addition, the invention represents a potential for saving energy compared to known LNG production processes since there will be fewer processing steps and, therefore, a reduced need for extra pressure increasing capacity, due to a more efficient utilization of the inherent energy at the wellhead or wellhead manifold.

From Figure 3 the energy balance of a condensation process also appears:

- the process according to the invention releases energy corresponding to h_5 - h_3, whereas
- a conventional process for liquefaction of natural gas releases energy corresponding to h_4 - h_3, such that
- the energy saving that this invention may give, is h_5 - h_4.

This situation is further demonstrated in Table 1 below which contains results of three simulated isentropic expansion processes under ideal theoretical conditions at a starting pressure and temperature of 200 bar and 20°C at the well manifold and ending pressures of 1 bar, 15 bar, and 40 bar, respectively. A pressure of 40 bar represents a typical pressure whereat conventional processes carry out separation and cleaning of the gas, and 1 bar and 15 bar represent alternative pressures in the storage tank.

Table 1 relates to an isentropic expansion process under ideal theoretical conditions for a gas comprising about 80% methane, 5% ethane, 2% propane, 2% N_2, 5% CO_2, and 6% C_{3+}, and is based on a starting condition corresponding to state 5 in Figure 3. The table indicates the values of available energy in the expansion process and the required

cooling needed for the condensation of all the fluid, after the expansion, into liquids, for ending conditions corresponding to states ②, ③ og ④ in Figure 3, respectively.

Tabell 1

State (see Fig. 3)	Pressure (bar)	Temp. (^{o}C)	Gas (% weight)	Liquid (% weight)	Free energy (kJ/kg)	Cooling need (kJ/kg)
②	1	-152,7	57,06	42,92	257	316
③	15	-93,4	64,52	35,48	147	287
④	40	-59,5	70,26	29,74	99	238

The *Gas* column indicates the gas percentage by weight after the drawing off of liquid in the expansion process.

The *Liquid* column indicates the liquid percentage by weight at the drawing off of liquid.

The *Free energy* column indicates the available free energy in the expansion process.

The *Cooling need* column indicates the cooling required to make the rest of the gas liquefied.

From the table it can be seen that the energy saved by using the method according to the invention amounts to 99 kJ/kg compared to a conventional process. A conventional process may utilize 33% and 61% of the available free energy when the pressure in the storage tank equals 15 bar and 1 bar, respectively. A process according to the present invention, however, is able to utilize all the free energy of the well stream.